ASSESSMENT OF VEGETATION IN PERMANENT FRESHWATER PONDS OF THE PROVINCE LANDS, CAPE COD NATIONAL SEASHORE, 2007

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Executive Summary

Aquatic vegetation in the permanent ponds within the Province Lands region of Cape Cod National Seashore was surveyed from July-August of 2007. A long-term monitoring protocol was designed for repeated sampling at permanent sites within 15 of the ponds. In addition, 25 ponds (including the former) were selected and inventoried for species presence/absence. A limit suit of environmental variables was also collected.

During this study, two State-Listed rare species (*Orontium aquaticum* and *Carex oligosperma*) were confirmed and new sites found. A handful of exotic species were also detected. Plant community composition among ponds differs primarily based on the relative abundances of three dominant species – *Nymphaea odorata* (white waterlily), *Juncus militaris* (military rush), and *Decodon verticillatus* (water willow). Species richness was highly variable among ponds and related to pond pH and organic matter content. More specifically, ponds with higher pH and less OM, which may be representative of ponds that are younger in age, harbored more taxa. Overall, species richness was very similar to that of dune slack wetlands – the ephemeral wetlands scattered throughout the dunes region of Provincetown and Truro.

In general, the methodology developed for this study was found to be very workable in the field. A few relatively minor difficulties were encountered and solutions and improvements are discussed below. However, it is expected that this protocol will generate good quality data for this ecosystem type.

Introduction

Description of resource

Much of the northern tip of Cape Cod is a vast system of sand dunes known as the Province Lands. This region of the Cape Cod peninsula began forming ~6,000 years ago as eroding sediments from the Atlantic-facing coastal bluffs were transported north and re-deposited by longshore currents. Sand from the elongating spit was then blown inland to widen the spit and form the characteristic hook of Provincetown. Topographic depressions were carved out by wind scour over time and subsequent sea level rise, which forced the fresh ground water table upwards, has resulted in the seasonal or permanent flooding of some of these depressions. Human activities, including the construction of roads which can impede horizontal flow may have also contributed to the ponding in this area (Winkler 1990).

The permanently flooded ponds in this region of CACO differ from kettle ponds on the glacial outwash plain that arose from depressions made by blocks of glacial ice. Kettle ponds are very deep compared with the Province Lands ponds. In fact, Province Lands ponds are true ponds (in the sense that they are shallow enough to support rooted vegetation throughout their extent) while most of the kettle ponds are technically lakes. Like kettle ponds, however, the Province Lands ponds are an important natural resource at CACO. They contribute to the aesthetic beauty of the region and are, of course, important ecologically. Within these waterbodies, aquatic plant communities thrive in an otherwise desert-like environment. They are one of the last refuges on the outer Cape for several uncommon plant species such as carnivorous pitcher plants and sundews. In addition, they are critical habitat for the reproduction and survival of invertebrates, amphibians (including the state-threatened Eastern Spadefoot Toad and Fowler's toads), and other wildlife. Thus, it is important to understand the structure and function of these ponds and how they are developing over time in order to better predict the future of this resource and to guide management decisions.

Threats and rationale for long term monitoring

Any major change in hydrology could have a significant impact on these ponds, particularly if the town of Provincetown ever decided to extract ground water from town-owned parcels of land within the park boundary. Continued development is also a concern, bringing with it various threats to water quality. In fact, Winkler (1990) reported that Duck and Bennett Ponds may have already been affected by leachate from the nearby Provincetown landfill. Broader threats include many aspects of global warming, especially changes in temperature (and therefore evaporation) and precipitation quantity and quality.

Biological threats include invasions of exotic species. *Lythrum salicaria* (purple loosestrife) has already invaded Great Pond - it was not present in 1977 according to Benedict (1977). The exotic strain of *Phragmites australis* (common reed) also occurs in several ponds and has the potential to spread. Another biological threat includes herbivory by Canada geese, which is thought to be the reason for the dramatic decline in *Orontium aquaticum* (golden club), a State Threatened species.

Objectives of monitoring

In accordance with the National Park Service's Inventory & Monitoring program to develop species inventories and implement monitoring protocols for all ecosystem types within Park units, the main objectives of this work were to survey and quantitatively assess plant communities in Province Lands ponds within CACO for the purpose of analyzing long term temporal trends. The work summarized in this report provides a baseline assessment of vegetation, a model for subsequent surveys, and a template for future analysis of change.

Methods

Study area - The area of study for this project was within the Beech Forest area of the Province Lands (Provincetown). Within this forested community there are numerous permanently-flooded, but relatively shallow ponds that support rooted aquatic vegetation throughout their extent. Figure 1 below shows the location and form of these sites.

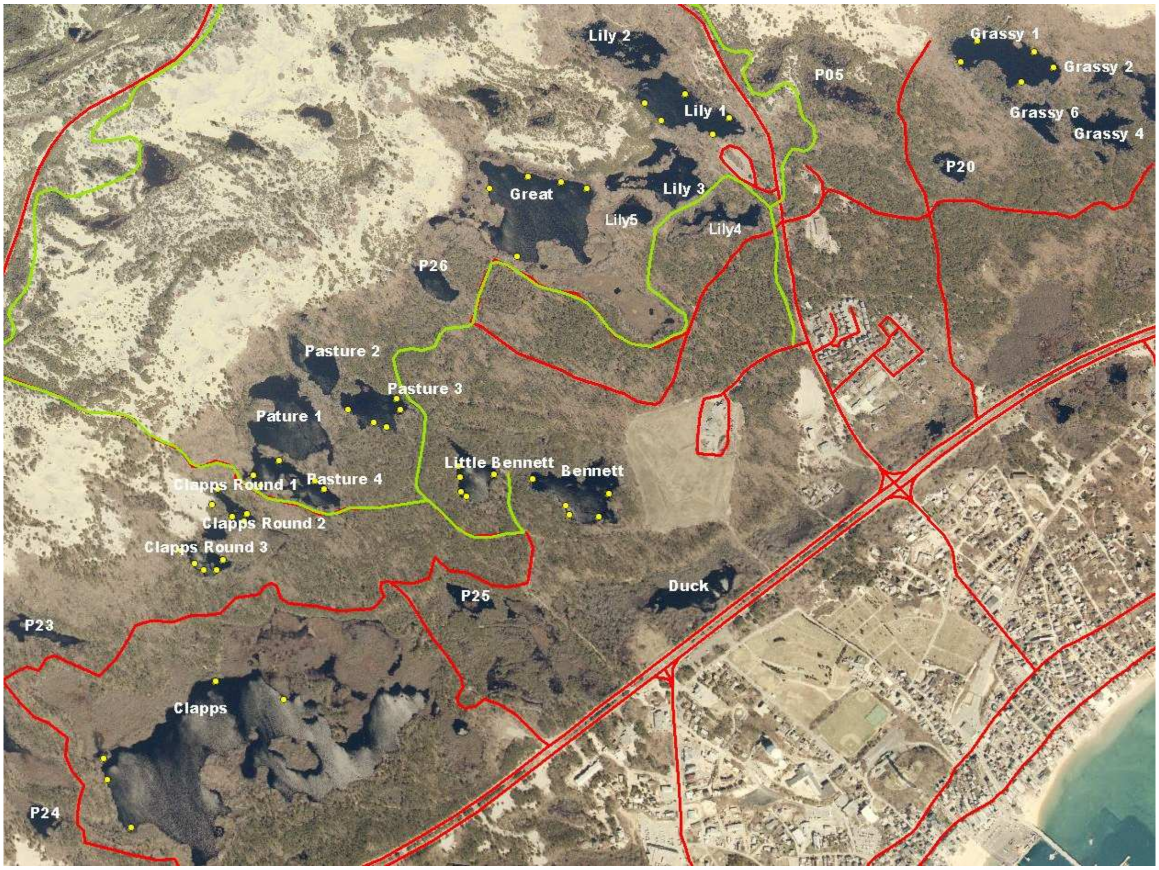

Figure 1. Map of PLands ponds (April 2001 aerial photo from MassGIS).

i) Establishment of transects and box-plots for assessment if vegetation - Fifteen ponds were randomly selected from among 30+ ponds in the Province Lands Beech Forest Area. These included Lily 1, Lily 2, Grassy 1, Grassy 4, Grassy 6, Bennett, Little Bennett, Pasture 1, Pasture 3, Pasture 4, P26, Clapps, Clapps Round 1, Clapps Round 3, and Great. Within each pond in this subset, 5 permanent 20-m transects and 100 m^2 (10 x 10 m) box-plots were established. To do this, locations were randomly selected from around the perimeter of the pond using ArcGIS 9.1 software. In the field, two PVC pipes were hammered into the pond bottom 10 m apart and roughly parallel with the shoreline at each location. The pipe was placed in emergent vegetation a few meters pondward of the shrub zone due to the difficulty of working in the dense woody vegetation without causing significant damage to it. There are also some non-trivial safety issues related to moving around in this kind of environment. The rationale for working outside the shrub zone was that the encroachment or retreat of the shrub border and species composition could still be tracked by measuring any changes in its distance to the landward side of the box plots (this is explained further below). Looking out pondward, the left poles designated the start points for each transect while both the left and right poles marked the landward corners for each box-plot. See Figure 2 for a diagram of the set up.

ii) Transect and box-plot vegetation surveys - Cover by species was estimated visually in contiguous 1-m^2 plots along the length of the 20-m transects. Cover classes were based on a modified Braun-Blanquet scale (1=0-1%, 2=1-5%, 3=5-10%, 4=10-25%, 5=25-50%, 6=50-75%, 7=75-100%. Plant cover by species was assessed in the same manner in the 10 x 10 m box-plots. Finally, the distance from the “base” of the box plot (i.e., the landward edge) to the shrub layer was measured using a two meter stick. Starting at the left point, the distance to the nearest overhanging vegetation was measured at meter intervals along the landward edge of the box-plot (Figure 2). If vegetation crossed into the box plot, it was recorded as a negative distance.

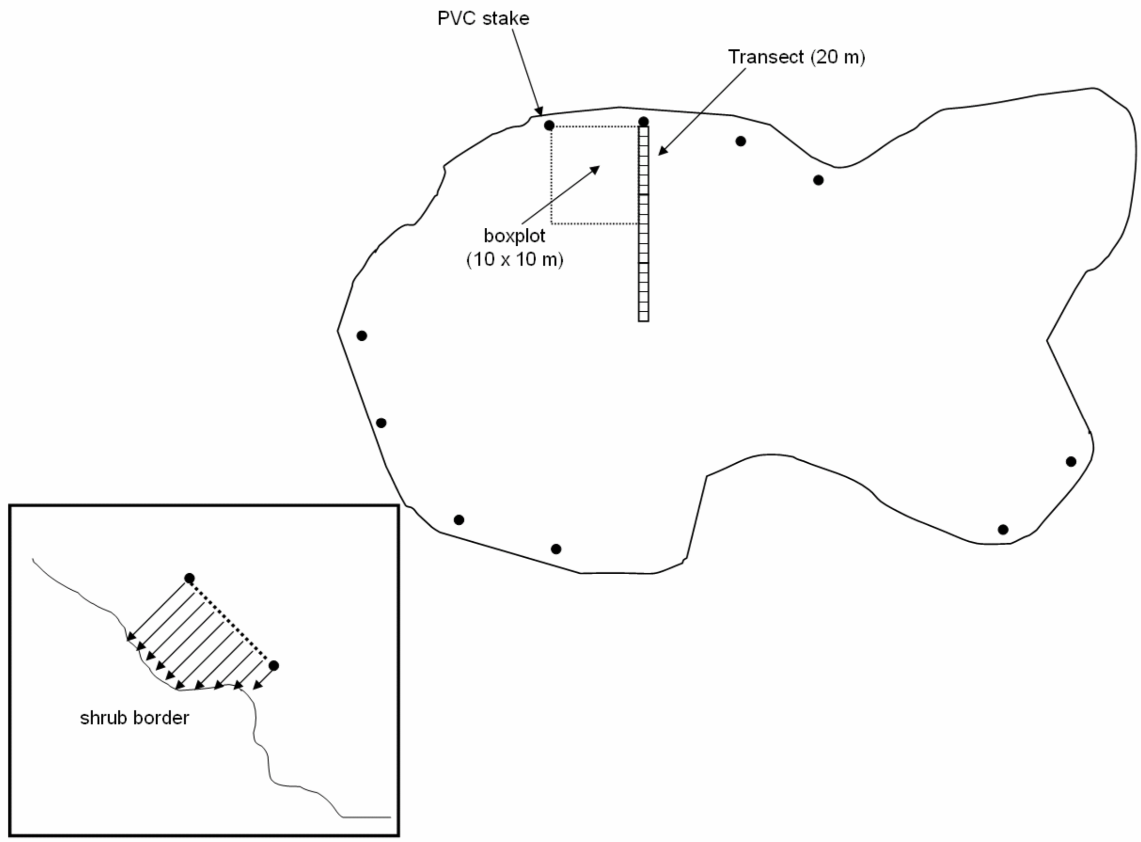

Figure 2. Diagram of transect and box-plot setup in PLands ponds.

iii) General species inventories - A system-wide survey of 25 ponds was conducted as a way to compile more complete species lists (inventories) for each pond since the transect and box-plot areas constitute a small portion of the ponds. Sites added to the original 15 discussed above were, Lily 3, Clapps Round 2, Grassy 2, P05, P20, P23, P24, P25, Duck, and Pasture 2. At each pond, the plants present in the bordering shrub zone and all emergent, floating, and submerged plants within the ponds themselves were identified and recorded. In addition each species was classified as Abundant (relatively large numbers of plants; constitute at least 10% of the total vegetation cover), Common (frequently observed, but not in large numbers; constitute 1-10% of the total vegetation cover), Uncommon (observed infrequently but in populations of > 10 individual plants; constitute < 1% of total vegetation cover), or Rare (present, but only as a few (< 10) individual plants). Finally, the general habitat type of the plant was noted by category (Shrub Zone, Emergent Vegetation Zone, Shrub Island, Floating Bog Mat, or Floating Vegetation Zone).

iv) Transect depth profiles – Water depths (recorded to the nearest cm) were taken manually (using a marked PVC pole) at meter intervals along each 20-m transect in June. To accurately compare depths among ponds with data collected at different times, water depth was repeatedly monitored at a single location (Lily 1) so that a rate of recession could be calculated and applied as a correction factor to compensate for the temporal staggering of data collection.

v) Sediment properties - Sediment cores were extracted from along each of the 20 m transects. Three cores were taken (10 cm depth) at 5m, 10m, and 15m along each of the five vegetation transects using a 4.8-cm diameter butyrate cylinder with a sharpened edge. The cores were then transported back to the lab and dried at 80°C to a constant weight. For particle-size fractionation, sediment > 2 mm was separated out by sieving and the remaining was further sieved in an automatic shaker and fractionated into six categories; 1-2 mm, 0.5-1 mm, 0.25-0.5 mm, 0.1-0.25 mm, 0.05-0.1 mm, and <0.05 mm. Each fraction was weighed and composited with the others. Sub-samples of the homogenized samples (< 2 mm) were then analyzed for organic matter content by weight-loss after ignition in a muffle furnace for 4 hrs. at 500°C.

vi) Water quality – surface water pH and conductivity were measured once in August along each transect using calibrated hand-held digital meters (Oakton™).

Statistical analysis - Non-metric multidimensional non-metric scaling (NMDS) of summed cover class values were frequently used to illustrate taxonomic differences among ponds (Clarke 1993). Similarity Percentages Analysis (SIMPER) quantified the contribution of individual species to Bray-Curtis dissimilarities among groups (Primer™ ver. 6). While Principle Components Analysis (PCA) is best suited for analyzing continuous, linear data, the technique can be used to illustrate the contributions of individual variables to patterns of ordinal data. Accordingly, multivariate datasets were subjected to PCA in order to reveal variables contributing most to directional trends in ordinal space. Univariate data was assessed using regression analysis and analysis of variance (ANOVA).

Results

Species richness (transects) – Along the transects, species richness was highly variable, ranging between 22 (Clapps Round 1) and 2 (Little Bennett) with an average of 7 species per pond. Species richness in the box-plots was very similar, ranging between 23 (Clapps

Round 1) and 2 (Little Bennett, Pasteur), and averaging 8 species per pond. Not surprisingly, the meander surveys generated higher numbers of species in every pond. A total of 88 vascular plant species were found in all ponds, although several identifications require re-examination (Appendix I). Clapps Round 1 and Lily had the highest number of species (37) while P05 had the lowest (14). These numbers are remarkably similar to dune slack wetlands (seasonally flooded) in the Province Lands, where species richness ranged between 2 and 35 with an average of 11 species per wetland (Smith et al. 2008).

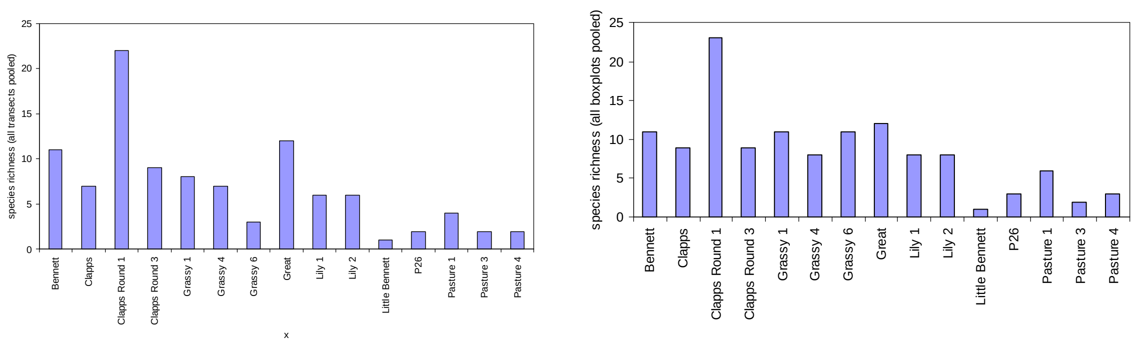

Figure 3. Species richness as assessed by transect (left) and box-plot (right) data.

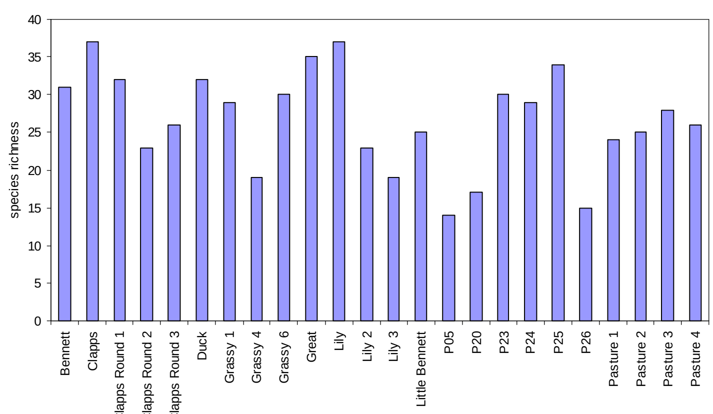

Figure 4. Species richness based on meander survey data.

Rare and exotic species - A number of non-native species were recorded. They were *Lythrum salicaria* (purple loosestrife; Great and Duck Pond), *Phragmites australis* (common reed; Clapps Round 1,2,3, Duck, Grassy 1, Grassy 6, Little Bennett, Pasteur 1)), *Typha angustifolia* (narrowleaf cattail; Great and Lily 1 ponds), *Iris pseudacorus* (yellow flag; Lily 1 pond), *Rosa multiflora* (multiflora rose; Duck pond), and *Potomogeton crispus* (curlyleaf pondweed; Great pond). For State-Listed rare species, *Orontium aquaticum* (golden club) was only listed as being present in Lily 3, despite its known presence in a number of other ponds. This is mostly likely due to timing as *Orontium* emerges and flowers in the early spring (May) and can be quite inconspicuous by July. *Utricularia subulata* (Zigzag Bladderwort; Special Concern) was recorded in P05, P23, and P24 but this ID needs confirmation (in 2008) as does *Eleocharis rostellata* in Duck, P05, and P20 (spike rush; Watch List). *Carex oligosperma* (Few-fruited sedge; State Threatened) was found in a few more ponds (Grassy 1, Bennett, Clapps Round 1) than what were originally listed in a previous rare-plant report (LeBlond 1989). Finally, one species not currently listed in the current CACO database of vascular plants was recorded. This was *Potomogeton crispus* (curlyleaf pondweed), which, as mentioned above, is an introduced species.

Vegetation Structure

Taxonomic variability among wetlands

i) Transects – Great Pond was very different than any other pond due to the high abundance of *T. angustifolium* and *L. salicaria*. With Great Pond excluded from the analysis, the spatial array of ponds in ordinal space showed that Clapps and Clapps Round 1 were taxonomically distinct from the other ponds, which were spread out in gradient fashion. Differences among ponds were primarily the result of different abundances of *Decodon verticillatus* and *Nymphaea odorata*.

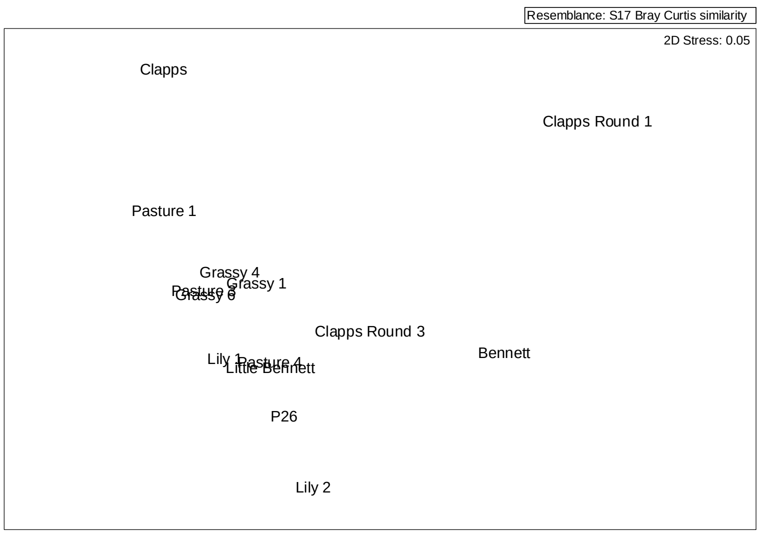

Figure 5. Transect taxonomic diversity among ponds (Great Pond excluded).

ii) Box-plots – Species composition in the 10 x 10 m box-plots exhibited a spatial arrangement similar to that of the transects, with Clapps and Clapps Round 1 separating out from the other ponds. The cover of *Juncus miltarius*, *Nyphaea odorata*, and *Decodon verticillatus* accounted for the highest proportion of dissimilarity among ponds.

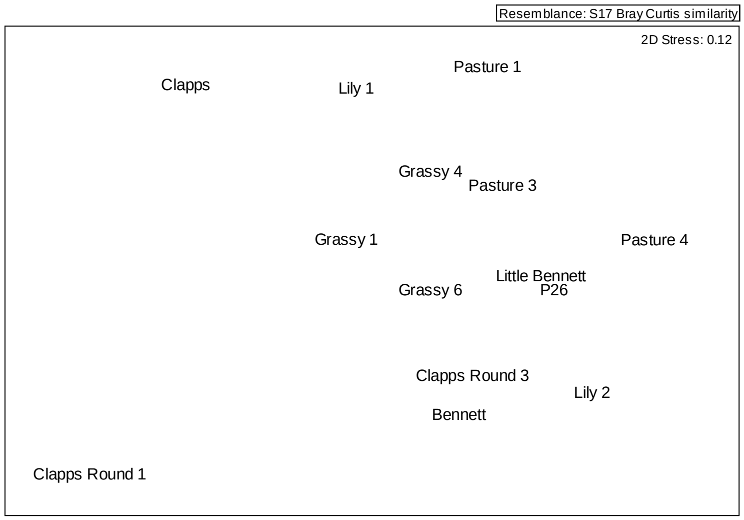

Figure 6. Box plot taxonomic diversity among ponds (Great Pond excluded).

When presence/absence data from pond-wide species lists (compiled for the larger set of ponds) is plotted, Great and Clapps Ponds still fall out from the rest (Figure 7). P05, P16, and Lily 1 are also separated from the cluster of remaining ponds.

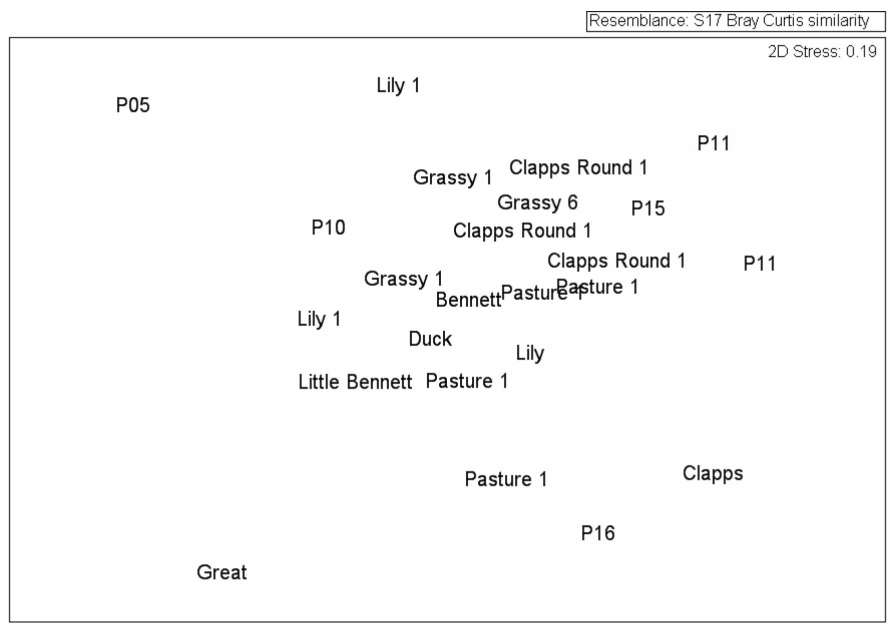

Figure 7. Taxonomic diversity based on presence/absence – meander survey (many graminoid species lumped to genus).

Structural variability among wetlands - The summer cover class values of shrubs, floating vegetation, and to a lesser extent trees is presented for transect and box-plot data in Figures 8 and 9, respectively. The vast majority of vegetation along transects consisted of either herbaceous forbs or graminoids. However, it is important to note that these data are primarily the result of how the transects were placed (i.e., pondward of the shrub zone due to the difficulty of working in the shrub vegetation)

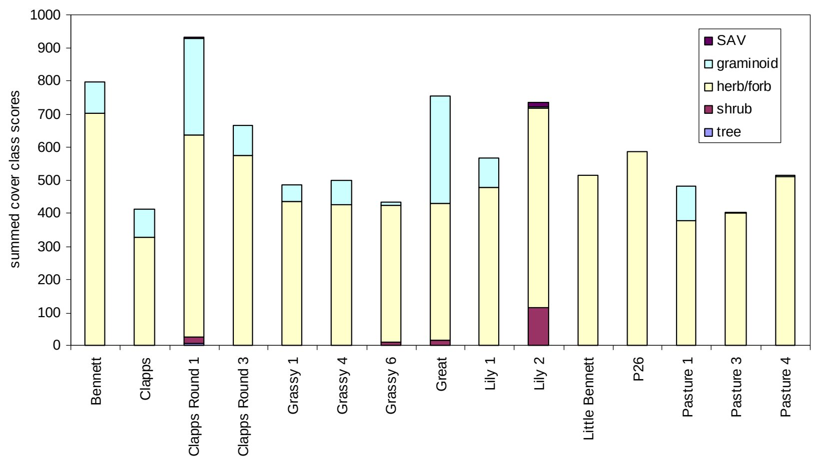

Figure 8. Structure of vegetation along transects.

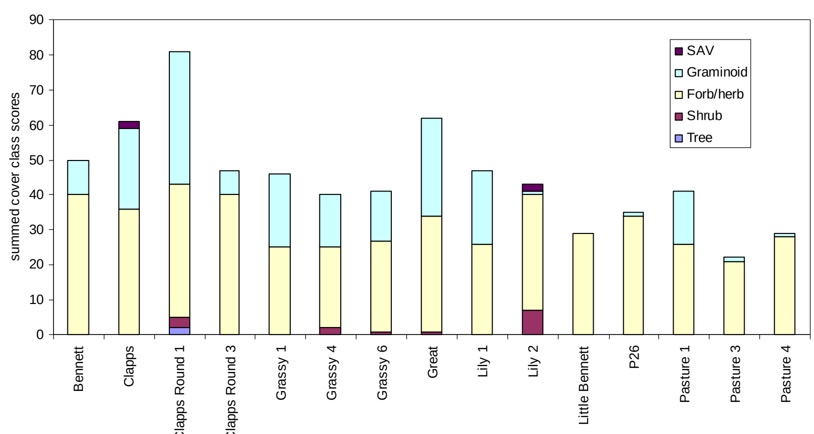

Figure 9. Structure of vegetation in box-plots.

Environmental variables - The organic matter content of soil cores was highly variable among ponds, as was bulk density (Figure 10a). Little Bennett, Clapps Round and Pasteur Ponds had the highest percentage of organic matter in the soil cores (> 50%) while Clapps Round had the lowest (< 5%). Compared to the dune slacks wetlands in this area, the ponds had more than an order of magnitude greater OM content (Smith et al. 2008). Bulk densities ranged between 0.09 g/cm^3 (Clapps Round 3) and 0.63 g/cm^3 (Clapps Round 1) (Figure 10b). These patterns illustrate the inverse relationship between organic matter content and bulk density, which are inversely related. Sediment particle size fractionation yielded somewhat less variable results (Figure 10c). The median particle size among ponds exhibited a much narrower range, with Grassy 1 having the lowest and Clapps Round 3 the highest (Figure 10d).

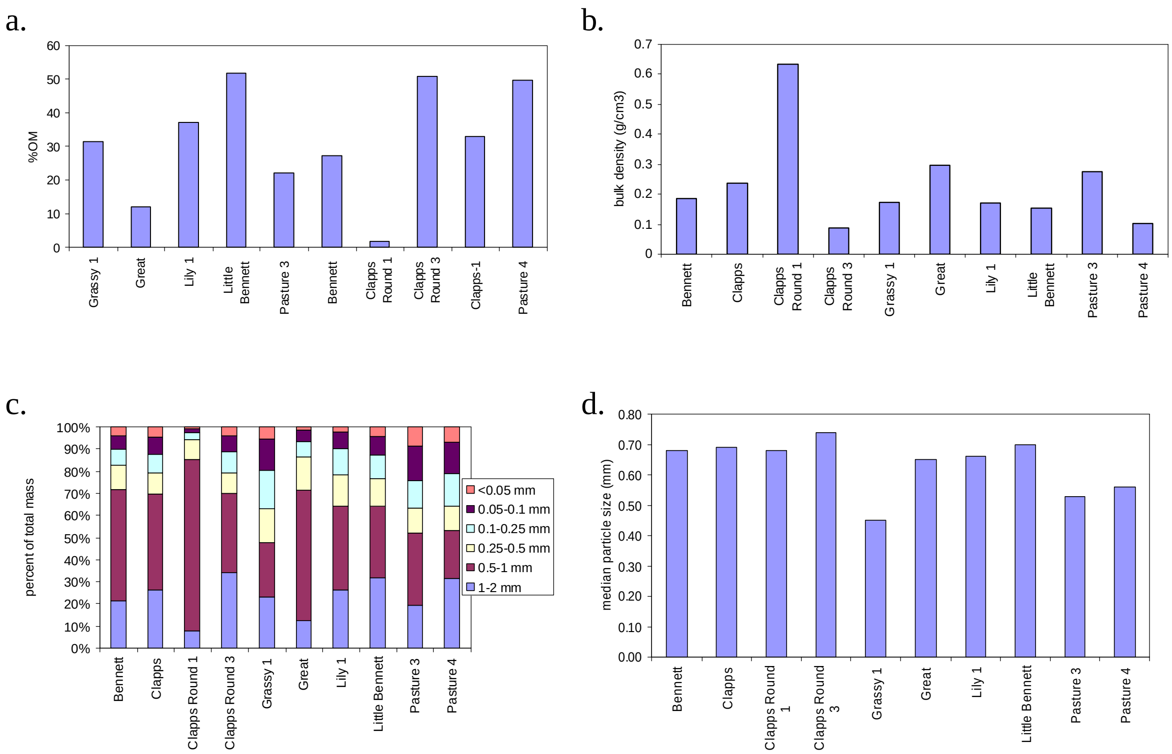

Figure 10. Soil core a) organic matter content, b) bulk density, c) particle size fractions, and d) median particle size by pond.

Surface water pH readings (average of 5 readings at each transect location, once during August) showed that the ponds were all quite acidic with pH values ranging between 3.84 (Bennett) and 5.86 (Clapps Round 3), with an average value of 4.95 (Figure 11).

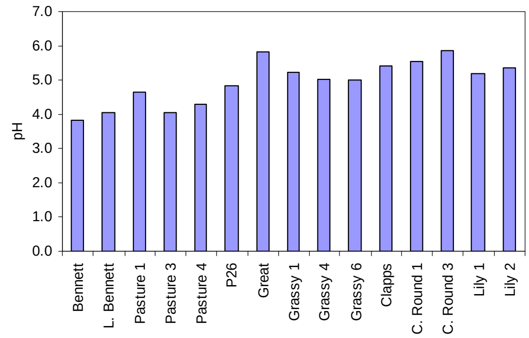

Figure 11. August pH values (surface water) by pond.

Mean values for the deepest points along the 5 transects in each pond are shown in Figure 12. The largest value (i.e., deepest) occurred in Clapps Pond (104 cm), the lowest (i.e., shallowest) in Lily 2 (54 cm). Mean maximum depth averaged 74 cm among all ponds.

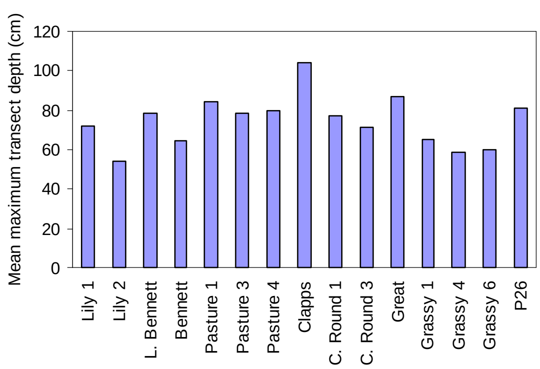

Figure 12. Mean maximum depths (cm) along transects by pond.

Pond areas varied by a factor of ~ 80, ranging between 0.21 ha (Clapps Round 2) and 17.6 (Great) (Table). However, most ponds fell within a range of 0.5 – 5 ha.

Table . Pond areas in hectares (calculated in ArcGIS 9.1).

Pond	area (ha)	Pond	area (ha)
Bennett	1.98	Lily 1	2.22
Clapps	17.6	Lily 2	1.63
Clapps Round 1	0.41	Lily 3	1.76
Clapps Round 2	0.21	Little Bennett	0.95
Clapps Round 3	0.56	P26	0.62
Grassy 1	2.3	Pasture 1	2.88
Grassy 4	0.91	Pasture 2	0.97
Grassy 6	0.54	Pasture 3	1.27
Great	5.04	Pasture 4	1.53

Relationships among variables

Regression analysis was used in an attempt to explain patterns of species richness. Unlike dune slack wetlands (seasonally flooded) within the Province Lands area (Smith et al. 2008), no relationship between species richness (box-plot data) and pond area or transect water depths were found (Figure 13). However, there was a significant negative correlation between species richness and organic matter content of soil cores (Figure 14). Species richness also declined with decreasing surface water pH (Figure 14). Organic matter content generally increases while pH declines with wetland age (Berendse et al. 1998). Thus, these relationships may reflect successional processes where, in the absence of any major disturbance, young to intermediate-aged ponds harbor more species than older ones (Glenn-Lewin 1992, Guo 1998) . If the pH differences are due simply to inherent physico-chemical properties of each pond the relationship makes sense given that species richness is typically lower under harsher (i.e., low pH) growing conditions (Whittaker 1974, Lichter 1998).

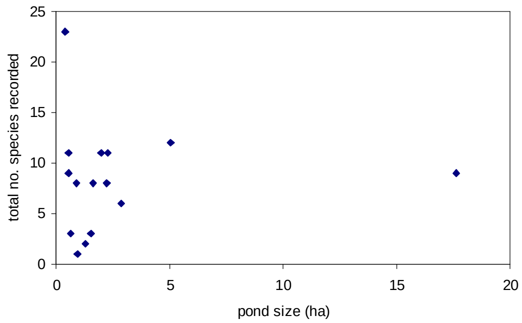

Figure 13. Species richness as a function of pond size.

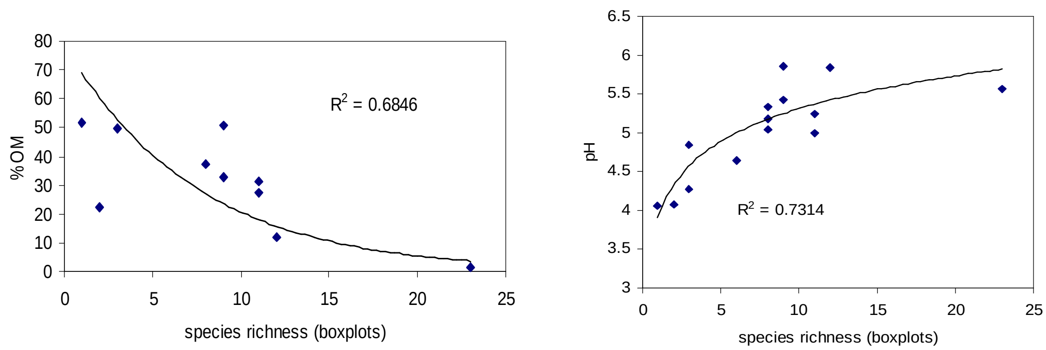

Figure 14. Species richness vs. organic matter content (%OM) and surface water pH.

Discussion

Anecdotally, the protocol described above worked fairly well and is expected to provide good quality long-term data on the vegetation within the Province Lands ponds. Of course, future surveys with a comparison of datasets and associated power analyses will provide critical information about the methods of monitoring and variables included. Thus, any conclusions made about this work are somewhat premature. Notwithstanding, much of the monitoring design was based on practical experience and lessons learned from studies of similar wetlands systems, including Kettle Ponds (Roman et al. 2001, Roman and Barrett 2004, Smith et al. 2008), and vernal ponds (Roman and Barrett 2004, Tupper 2006, Smith et al. 2007).

Problems encountered and recommendations for future monitoring

Some areas of certain ponds simply could not be explored in a way that did not seriously compromise the safety of the field crew. For example, a large portion of Clapps Pond is comprised of floating peat mats ("quaking bogs") which are extremely unstable and in some places virtually impenetrable due to the density of shrubs. As a result, the field crew could only survey vegetation that they could see and access from the edge of the open water portion of the pond. Thus, an unknown number of species were not recorded at sites like these. This is not necessarily a major shortcoming of the monitoring protocol because the focus of long-term monitoring is more on temporal trends than on characterizing entire pond communities and assessing variability among ponds during a single point in time. Another problem relates to the seasonality of certain taxa. For example, *Orontium aquaticum* is a species that is very conspicuous in May but difficult to detect by July. Various orchid species also have short periods of flowering after which they are difficult to find. However, these few species comprise a minute portion of the overall plant communities.

Finally, water level is a critical factor regulating the abundance of many species, particular herbaceous taxa (Smith et al. 2007). As such, subsequent monitoring should take place in a year when water levels are relatively similar to those measured in 2007.

In reality, however, this may be a very difficult guideline to follow. As such, it may be advisable to transform abundance data into presence/absence as a way to reduce the influence of year-to-year water level fluctuations.

In conclusion, this work provided baseline quantitative data on the vegetation of Province Lands ponds to serve the needs of long term monitoring. The real value of this study will become apparent when subsequent vegetation surveys are done and temporal trends can be elucidated. This would have been very useful in the past given that some major changes in certain species have occurred. For example, the rapid decline of *Orontium aquaticum* and the proliferation of *Lythrum salicaria* are two trends that, unfortunately, were never documented quantitatively. As such, the timelines over which these changes occurred are unknown. It is expected that long-term monitoring will capture such developments. Because they can happen in relatively short time periods, it is recommended that the next Province Lands ponds vegetation surveys be conducted every five years. The surveys should be done in the exact same manner so that an analysis of methods and variables can be undertaken.

Acknowledgements

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Appendix I. Species list compiled for Province Lands ponds in 2007 (asterisks denote dpecies identifications that are suspect and need confirmation).

Acer rubrum
Amelanchier arborea
Betula populifolia
Boehmeria cylindrica
Brasenia schreberi
Calamagrostis canadensis
Carex oligosperma
Carex sparganioides *
Cephalanthus occidentalis
Ceratophyllum demersum
Chamaedaphne calyculata
Cladium mariscoides
Clethra alnifolia
Decodon verticillatus
Drosera intermedia
Drosera rotundifolia
Dulichium arundinaceum
Eleocharis acicularis
Eleocharis obtusa
Eleocharis olivacea
Eleocharis palustris
Eleocharis parvula
Eleocharis pauciflora
Eleocharis robbinsii
Eleocharis robbinsii
Eleocharis rostellata *
Eragrostis hypnoides *
Eriocaulon aquaticum
Eriocaulon septangulare
Eriophorum virginicum
Euthamia graminifolia
Gratiola aurea
Euthamia sp.
Ilex glabra
Ilex verticillata
Iris pseudacorus
Juncus acuminatus
Juncus articulatus
Juncus bufonius
Juncus pelocarpus
Juncus militaris
Kalmia angustifolia
Ludwigia palustris
Lyonia ligustrina
Lysimachia terrestris
Lythrum salicaria
Mentha arvensis
Myriophyllum humile
Nymphaea odorata
Nyssa sylvatica
Onoclea sensibilis

Orontium aquaticum
Osmunda regalis
Photinia melanocarpa
Phragmites australis
Pogonia ophioglossoides
Pontederia cordata
Potamogeton crispus
Potamogeton epihydrus
Rhododendron viscosum
Rhynchospora alba
Rhynchospora capitellata
Rhynchospora fusca
Rosa multiflora
Rosa palustris
Salix nigra
Sarracenia purpurea
Schoenoplectus acutus
Schoenoplectus subterminalis
Scirpus cyperinus
Sium suave
Smilax rotundifolia
Solanum dulcamara
Sparganium americanum
Sparganium angustifolium
Sphagnum spp.
Spiraea alba
Spiraea tomentosa
Thelypteris palustris
Typha angustifolia
unknown grass
Utricularia cornuta
Utricularia subulata
Vaccinium corymbosum
Vaccinium macrocarpon
Vallisneria americana
Woodwardia virginica
Xyris difformis
Zizania aquatica

Appendix II. Coordinates for transect/box-plot sites. Locations are the middle point between left and right box-plot markers (UTM NAD83).

Pond	Site ID	Xcoord	Ycoord
Bennett	BNT-1	400696	4657021
Bennett	BNT-2	400785	4656936
Bennett	BNT-3	400804	4656917
Bennett	BNT-4	400871	4656919
Bennett	BNT-5	400895	4656980
Clapps	CL-1	399704	4656140
Clapps	CL-2	399893	4656509
Clapps	CL-3	400064	4656463
Clapps	CL-4	399620	4656236
Clapps	CL-5	399616	4656299
Clapps Round 1	CR1-1	399968	4656940
Clapps Round 1	CR1-2	399926	4656932
Clapps Round 1	CR1-3	399986	4656916
Clapps Round 1	CR1-4	399880	4656992
Clapps Round 1	CR1-5	399921	4656974
Clapps Round 3	CR3-1	399818	4656838
Clapps Round 3	CR3-2	399913	4656819
Clapps Round 3	CR3-3	399842	4656792
Clapps Round 3	CR3-4	399866	4656774
Clapps Round 3	CR3-5	399910	4656788
Grassy 1	GR1-1	401784	4658080
Grassy 1	GR1-2	401831	4658146
Grassy 1	GR1-3	401946	4658025
Grassy 1	GR1-4	402033	4658072
Grassy 1	GR1-5	401970	4658109
Grassy 4	GR4-1	402206	4657888
Grassy 4	GR4-2	402189	4657904
Grassy 4	GR4-3	402158	4657945
Grassy 4	GR4-4	402086	4657912
Grassy 4	GR4-5	402119	4657885
Grassy 6	GR6-1	402016	4657946
Grassy 6	GR6-2	401946	4657967
Grassy 6	GR6-3	402030	4657885
Grassy 6	GR6-4	401974	4657910
Grassy 6	GR6-5	401956	4657930
Great	GRT-1	400855	4657746
Great	GRT-2	400662	4657577
Great	GRT-3	400764	4657781
Great	GRT-4	400587	4657743
Great	GRT-5	400693	4657797
Lily 2	L2-1	401036	4658098
Lily 2	L2-2	400947	4658064
Lily 2	L2-3	401007	4658141
Lily 2	L2-4	400917	4658154
Lily 2	L2-5	400859	4658113
Lily 1	L1	401092	4658008
Lily 1	L2	401025	4657922
Lily 1	L3	401163	4657890
Lily 1	L4	401196	4657948

Lily 1	L5	400986	4657974
Little Bennett	LBNT-1	400522	4656970
Little Bennett	LBNT-2	400509	4656986
Little Bennett	LBNT-3	400516	4657012
Little Bennett	LBNT-4	400506	4657056
Little Bennett	LBNT-5	400605	4657032
P26	P26-1	400483	4657518
P26	P26-2	400468	4657540
P26	P26-3	400503	4657476
P26	P26-4	400450	4657487
P26	P26-5	400416	4657517
Pasteur 4	PST4-1	400177	4656991
Pasteur 4	PST4-2	399986	4657039
Pasteur 4	PST4-3	399985	4657014
Pasteur 4	PST4-4	400137	4657017
Pasteur 4	PST4-5	400079	4657056
Pasteur 1	PST1-1	400046	4657193
Pasteur 1	PST1-2	400145	4657083
Pasteur 1	PST1-3	399984	4657144
Pasteur 1	PST1-4	400111	4657227
Pasteur 1	PST1-5	400039	4657267
Pasteur 3	PST3-1	400373	4657215
Pasteur 3	PST3-2	400236	4657193
Pasteur 3	PST3-3	400293	4657159
Pasteur 3	PST3-4	400350	4657151
Pasteur 3	PST3-5	400333	4657233

Appendix III. Transect site locations (points represent middle point between the two PVC markers demarcating the shoreward corners of the box plots).

Pond	Site ID	Xcoord	Ycoord
Bennett	BNT-1	400696	4657021
Bennett	BNT-2	400785	4656936
Bennett	BNT-3	400804	4656917
Bennett	BNT-4	400871	4656919
Bennett	BNT-5	400895	4656980
Clapps	CL-1	399704	4656140
Clapps	CL-2	399893	4656509
Clapps	CL-3	400064	4656463
Clapps	CL-4	399620	4656236
Clapps	CL-5	399616	4656299
Clapps Round 1	CR1-1	399968	4656940
Clapps Round 1	CR1-2	399926	4656932
Clapps Round 1	CR1-3	399986	4656916
Clapps Round 1	CR1-4	399880	4656992
Clapps Round 1	CR1-5	399921	4656974
Clapps Round 3	CR3-1	399818	4656838
Clapps Round 3	CR3-2	399913	4656819
Clapps Round 3	CR3-3	399842	4656792
Clapps Round 3	CR3-4	399866	4656774
Clapps Round 3	CR3-5	399910	4656788
Grassy 1	GR1-1	401784	4658080
Grassy 1	GR1-2	401831	4658146
Grassy 1	GR1-3	401946	4658025
Grassy 1	GR1-4	402033	4658072
Grassy 1	GR1-5	401970	4658109
Grassy 4	GR4-1	402206	4657888
Grassy 4	GR4-2	402189	4657904
Grassy 4	GR4-3	402158	4657945
Grassy 4	GR4-4	402086	4657912
Grassy 4	GR4-5	402119	4657885
Grassy 6	GR6-1	402016	4657946
Grassy 6	GR6-2	401946	4657967
Grassy 6	GR6-3	402030	4657885
Grassy 6	GR6-4	401974	4657910
Grassy 6	GR6-5	401956	4657930
Great	GRT-1	400855	4657746
Great	GRT-2	400662	4657577
Great	GRT-3	400764	4657781
Great	GRT-4	400587	4657743
Great	GRT-5	400693	4657797
Lily 2	L2-1	401036	4658098
Lily 2	L2-2	400947	4658064
Lily 2	L2-3	401007	4658141
Lily 2	L2-4	400917	4658154

Lily 2	L2-5	400859	4658113
Lily 1	L1	401092	4658008
Lily 1	L2	401025	4657922
Lily 1	L3	401163	4657890
Lily 1	L4	401196	4657948
Lily 1	L5	400986	4657974
Little Bennett	LBNT-1	400522	4656970
Little Bennett	LBNT-2	400509	4656986
Little Bennett	LBNT-3	400516	4657012
Little Bennett	LBNT-4	400506	4657056
Little Bennett	LBNT-5	400605	4657032
P26	P26-1	400483	4657518
P26	P26-2	400468	4657540
P26	P26-3	400503	4657476
P26	P26-4	400450	4657487
P26	P26-5	400416	4657517
Pasteur 4	PST4-1	400177	4656991
Pasteur 4	PST4-2	399986	4657039
Pasteur 4	PST4-3	399985	4657014
Pasteur 4	PST4-4	400137	4657017
Pasteur 4	PST4-5	400079	4657056
Pasteur 1	PST1-1	400046	4657193
Pasteur 1	PST1-2	400145	4657083
Pasteur 1	PST1-3	399984	4657144
Pasteur 1	PST1-4	400111	4657227
Pasteur 1	PST1-5	400039	4657267
Pasteur 3	PST3-1	400373	4657215
Pasteur 3	PST3-2	400236	4657193
Pasteur 3	PST3-3	400293	4657159
Pasteur 3	PST3-4	400350	4657151
Pasteur 3	PST3-5	400333	4657233